BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iaşi,
Tomul LX (LXIV), Fasc. 2, 2014
Secţia
CONSTRUCŢII DE MAŞINI

DYNAMIC ANALISYS BY THE NUMERICAL SIMULATION OF THE VARIATION OF THE MECHANICAL PARAMETERS OF THE SOLENOID INJECTOR

BY

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Received: September 12, 2014
Accepted for publication: October 10, 2014

Abstract. The simulation of the structure and operation of a preset model allows the creation of all the possible situations (states) of the model and thus enables one to check the existence of the properties set during the analysis stage. The fact that these properties are not confirmed supports the existence of one or several errors either in the structure of the model, or in the determination of its properties. Therefore, only simulation is able to finally validate the achievement of the operation characteristics set by design.

Our paper is aimed at the dynamic analysis of the variation of mechanical parameters, *i.e.* the control valve and injection nozzle needle travel, depending on the electric signal applied to the injector coil.

The analysis of the characteristics shown in Figs. 2,...,4, reveals that on the application of the step-like electrical input signal the control valve starts to open, followed by the opening of the injection nozzle. The operation mode is stable, the unit-step responses are aperiodical with delay and down time, the responses may be approximated with a 1st order element with delay.

Key words: injector, simulation, injection, valve.

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1. Introduction

The simulation of the structure and operation of a preset model allows the creation of all the possible situations (states) of the model and thus enables one to check the existence of the properties set during the analysis stage. The fact that these properties are not confirmed supports the existence of one or several errors either in the structure of the model, or in the determination of its properties. Therefore, only simulation is able to finally validate the achievement of the operation characteristics set by design.

Given the high number of fields to which simulation applies as a method of analysis of system and process behavior, many programs and function libraries used in simulation were created and developed. Matlab/Simulink and AMESim are some of the most used programs in engineering system simulation.

The digital simulation of systems including electro-hydraulic components is much simpler with AMESim and allows the fast optimization of the constructive and functional parameters required in practice (Beucher & Weeks, 2008; Watton, 1989; Călinoiu *et al*., 1998; Negoiță, 2011).

Given the numerous possibilities provided by language for the development of submodels by means of interdisciplinary libraries, AMESim was implemented as a basic design tool by reputed system manufacturers (Beucher & Weeks, 2008; Watton, 1989; Călinoiu *et al*., 1998; Negoiță, 2011; http://www.plm.automation.; http://www.mathworks.com/).

Our paper is aimed at the dynamic analysis of the variation of mechanical parameters, *i.e.* the control valve and injection nozzle needle travel, depending on the electric signal applied to the injector coil.

2. The Conceptual Model for the Numerical Simulation of the Injector Using the AMESim Medium

The unit-step response, *i.e.* control valve and injection nozzle needle displacement variation, is analyzed for three pressure values, namely 1800, 800 and 400 bar.

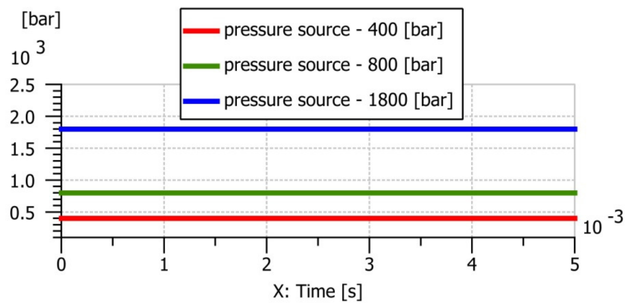

Fig. 1 − The injection pressure required.

Figs. 2,…,4 show the control valve and injection nozzle opening variation depending on the electrical control signal sent from the ECU (the car computer) to the injector coil.

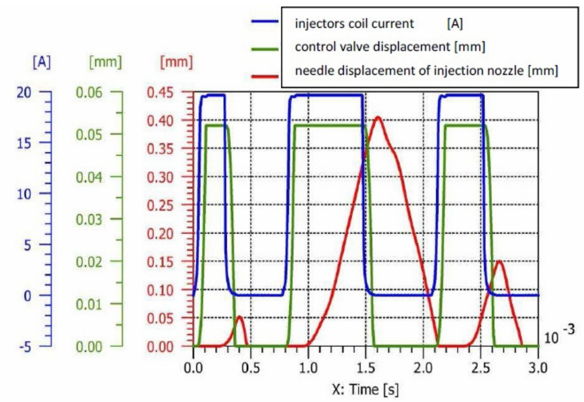

Fig. 2 – The step response of control valve opening and the injection nozzle at the pressure of 1800 bar.

The following data were used for solenoid injector operation simulation:

– working fluid for simulations ISO 4113
– the viscosity of the working fluid at 40°C 2.5 cSt
– fluid temperature 80°C
– vapour pressure 0.002 bar
– injection hole diameter 0.12 mm
– number of injection holes 6
– supply current injector coil 20 A

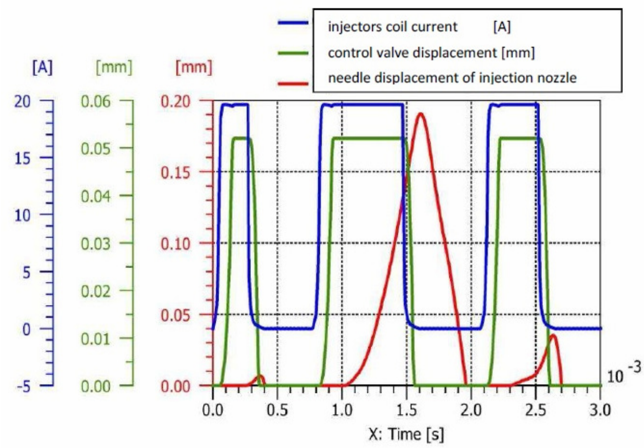

Fig. 3 – The step response of control valve opening and the injection nozzle at the pressure of 800 bar.

The dynamic performance of the injector is defined by the quality of the transient response.

We analyzed the unit-step response the parameters of which are performance indices of the dynamic systems: overshooting, transfer factor, up-slope time, transient regimen time.

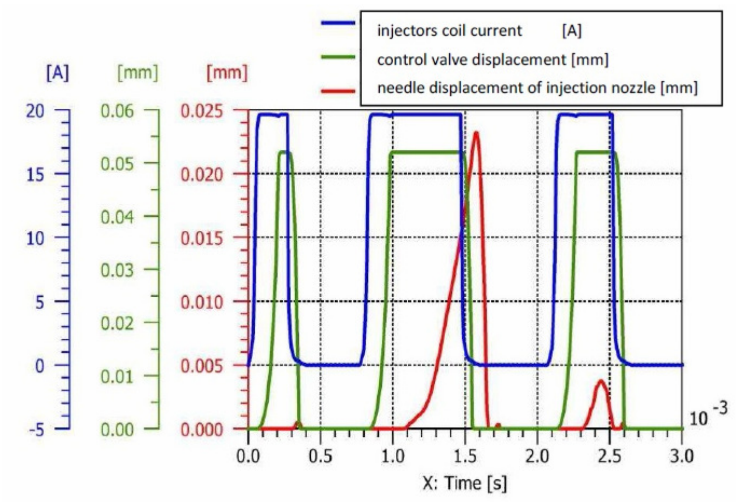

Fig. 4 − The step response of control valve opening and the injection nozzle at the pressure of 400 bar.

The analysis of the characteristics shown in Figs. 2,..., 4, reveals that on the application of the step-like electrical input signal the control valve starts to open, followed by the opening of the injection nozzle. The operation mode is stable, the unit-step responses are aperiodical with delay and down time, the responses may be approximated with a 1st order element with delay.

There is a delay between the application of the input signal and the opening of the valve, delay which is due to the forces of inertia of the components in motion.

There is a bigger delay between the opening of the control valve and the opening of the injection nozzle, delay which is due to the forces of inertia and to the time required for the emptying of the injector's control chamber.

The decrease in the injector feeding pressure leads to the increase of the delays and to the shortening of the injection nozzle valve travel, which influences the injected outflow.

3. Conclusions

1. The unit-step responses obtained in the study of an auto injector for various pressure steps allow the analysis of the functioning of the injector and

its components (valve and injection nozzle), during the stages corresponding to injection: pre-injection, main injection and post-injection

2. The analysis of the characteristics obtained for three pressure stages, *i.e.* 400, 800, 1800 bar, enabled us to conclude that: the operation mode is stable, the unit-step responses are aperiodical with delay and down time.

3. The analysis of the dynamic mode allows constructive-functional corrections of the analyzed injector.

REFERENCES

Beucher O., Weeks M., *Introduction to Matlab&Simulink*: *A Project Approch.* Third Edition, Revision & Reprint Copyright by Infinity Science Press LLC, 2008.

Călinoiu C., Vasiliu D., Vasiliu N., Catana I., *Modelarea, simularea şi identificarea experimentală a servomecanismelor hidraulice*. Edit. Tehnică, Bucureşti, 1998.

http://www.mathworks.com/products/simulink/

http://www.plm.automation.siemens.com/en_us/products/lms/imagine-lab/amesim/index.shtml

Negoiţă G.C., *Research on Dynamics Volume Hydraulic Transmission*. Universitatea Politehnică din Bucureşti, Facultatea de Energetică, Ph. D. Diss, 2011.

Watton J., *Fluid Power Systems: Modeling*, *Simulation*, *Analog and Microcomputer Control*. Englewood Cliffs, NJ: Prentice- Hall, 1989.

ANALIZA DINAMICĂ PRIN SIMULARE NUMERICĂ
A VARIAŢIEI PARAMETRILOR
MECANICI A INJECTORULUI CU SOLENOID

(Rezumat)

Simularea structurii şi a funcţionării unui model stabilit permite obţinerea tuturor situaţiilor (stărilor) posibile ale modelului şi deci asigură, verificarea existenţei proprietăţilor stabilite în etapa de analiză. Faptul că aceste proprietăţi nu sunt confirmate indică prezenţa uneia sau mai multor erori fie în alcătuirea modelului, fie în determinarea proprietăţilor acestuia.

Prin urmare, numai prin simulare rezultă o validare definitivă a obţinerii caracteristicilor de funcţionare stabilite prin proiectare.

Lucrarea urmăreşte analiza dinamică a variaţiei parametrilor mecanici, respectiv cursa valvei de control şi a acului duzei de injecţie funcţie de semnalul electric aplicat bobinei injectorului.

Din analiza caracteristicilor prezentate în figurile 2,…,4, se constată că la aplicarea semnalului electric de intrare de tip treaptă, începe deschiderea valvei de control, după care se deschide duza de injecţie, regimul de funcţionare este stabil, răspunsurile indiciale sunt de tip aperiodic cu întârziere şi timp mort, răspunsurile pot fi aproximate cu un element de ordin I cu întârziere.